Exploring the critical success factors influencing BIM level 2 implementation in the UK construction industry: the case of SMEs

Abu Awwad, K. W., Shibani, A. & Ghostin, M.

Original citation & hyperlink:
Abu Awwad, KW, Shibani, A & Ghostin, M 2020, 'Exploring the critical success factors influencing BIM level 2 implementation in the UK construction industry: the case of SMEs', International Journal of Construction Management.
https://dx.doi.org/10.1080/15623599.2020.1744213

DOI 10.1080/15623599.2020.1744213
ISSN 1562-3599
ESSN 2331-2327

Publisher: Taylor and Francis

This is an Accepted Manuscript of an article published by Taylor & Francis in International Journal of Construction Management on 31/03/2020, available online: http://www.tandfonline.com/10.1080/15623599.2020.1744213

Exploring the Critical Success Factors Influencing BIM Level 2 Implementation in the UK Construction Industry: The Case of SMEs.

Khaled Abu Awwad

PhD Researcher, School of Energy, Construction and Environment, Coventry University, Coventry, United Kingdom

Email: abuawwa2@uni.coventry.ac.uk

Abdussalam Shibani

Lecturer in Construction and Project Management, School of Energy, Construction and Environment, Coventry University, Coventry, United Kingdom

Email: ab1732@coventry.ac.uk

Michel Ghostin

PhD Researcher, School of Energy, Construction and Environment, Coventry University, Coventry, United Kingdom

Email: ghostinm@uni.coventry.ac.uk

Exploring the Critical Success Factors Influencing BIM Level 2 Implementation in the UK Construction Industry: The Case of SMEs.

Abstract

The implementation of BIM Level 2 in the United Kingdom (UK) construction sector has increased significantly in the last decade, particularly after the UK government mandated the use of BIM in all public projects by 2016. Despite this, there are many indicators that BIM implementation is a main concern for large companies, while Small and Medium-sized enterprises (SMEs) are lagging behind in adopting and implementing this new technology. This slow adoption, has led to a competitive disadvantage for SMEs in public projects and possibly private projects, which is exacerbated by the limited research focusing on the implementation of BIM Level 2 within SMEs. Therefore, the aim of this study is to bridge this gap and explore the Critical Success Factors (CSFs) influencing BIM Level 2 implementation in SMEs, as well as identifying their importance throughout the implementation process. To achieve this aim, a qualitative research approach was adopted involving 25 semi-structured interviews with BIM experts in three SMEs in the UK. The study concluded by identifying 15 factors, which includes 3 new factors and 12 factors previously mentioned in the literature. All 15 factors were then given an importance level based on how influential they were during the implementation process.

Keywords: Building Information Modelling, BIM, Critical Success Factors, CSFs, Small and Medium-sized Enterprises, SMEs, United Kingdom, UK.

Introduction.

The evolution of Information and Communication Technology (ICT) has created significant opportunities for improving project delivery. The benefits of ICT have encouraged many construction companies to invest in this new technology (Peansupap *et al.,* 2005). However, the adoption of the technology for construction has been slow when compared to manufacturing and aerospace. KPMG's annual report (2016) reported that 75% of construction and engineering executives were not using advanced data to control project estimation and performance.

The reason for this slow adoption argued Peansupap *et al.*, (2005) was due to: the unique aspect of construction, the complex nature of the industry, the immaturity of ICT, financial restrictions, and a lack of understanding of the BIM implementation. Stewart *et al.*, (2004) added that the slow adoption was due to supply chain decomposition, an absence of client leadership, resistance to change, a lack of technology awareness, a low level of training and the need for investment.

In the UK, the Architecture Engineering and Construction industry is the sector which contributes the most to the UK economy (Myres 2013). According to the British Standards Institute 99% of the companies in the sector were SMEs (Department for Business Innovation & Skills, 2014). Also, according to Robson *et al.*, (2014), in the UK there are 950,000 SMEs which account for almost 80% of the total production cost in the UK construction industry.

In 2016, the UK government mandated the use of BIM Level 2 in all public projects worth £5M and over (Cabinet Office 2012). To make this possible, many frameworks have been developed to support organisations and governments to achieve their strategies (Wu et al 2017). One of the most acknowledged frameworks was presented by Bews and Richards (2008). This framework is composed of three main levels, introduced by a PreBIM or level 0 stage. The National Building Specification (NBS) published a guide which clarifies and defines each BIM level (NBS 2017). According to NBS (2017), BIM Level 0 is the level which requires no collaboration. At this level 2D CAD is utilised for data production. The results are either produced on paper, electric prints or both. Currently, most of the companies in the industry have advanced past this level. The next level proposed by Bews and Richards (2008) is BIM Level 1 where many organisations are presently working at this level. This includes a mix of 3D CAD and 2D CAD to create data and information. This data is shared electronically which is carried out from a Common Data Environment (CDE), which is usually managed by the contractor. However, the models are not shared between the stakeholders of the project. Moving towards the framework, organisations and governments will start implementing BIM Level 2 where collaboration takes place, but although all stakeholders use their own 3D CAD, it is not essentially a shared model. The collaboration element is evidenced by the sharing of information between parties which is vital at this level. The design data is shared by using a common file format which shows the association between information for all parties in order to form a BIM model. Consequently, any CAD software used by parties should be capable of being exported to the common file formats of IFC (Industry

Foundation Class) or COBie (Construction Operations Building Information Exchange). The last level proposed in the framework is BIM Level 3, this level represents full collaboration and integration of all the parties using one shared model referred to as *n*D. All parties can have access and make modifications to this model, which helps to remove the risk of information conflicts.

Despite these efforts to implement BIM gradually, it has been found that BIM Level 2 is mainly used by large companies, while SMEs were lagging behind in the adoption of the new technology (SmartMarket Report, 2012). Indeed, SMEs were slow to embrace BIM, and thus were missing out on both public and private sector projects. It has been reported that 40% of SMEs miss out on 90% of the public projects they bid for, and more than 50% of SMEs have recognised a drop in their success rate on bidding for public construction projects in the last 5 years (Federation of Master Builders 2013). Blackwell (2012) argued that if SMEs continue to be slow in embracing this new technology, they could lose out in both national and international markets.

On the other hand, it can be argued that in spite of the numerous reports frameworks for its implementation there is still a lack of knowledge of BIM within the industry. A survey by Dunton (2016) showed that generally the construction industry was 'Level 2 BIM positive' but not 'Level 2 BIM aware'. According to Hunt (2015), there was a lack of awareness of BIM, where the focus was on tools and software and little attention was being given to the collaborative processes and working environment which is the main advantage of the BIM approach. In addition, Boutle (2017) stated that the level of awareness was even less in small companies and supply-chain organisations, where they are still even facing issues with BIM Level 1.

Considering this, the aim of this study is to explore the adoption of BIM Level 2 in SMEs, and identify the CSFs influencing adoption and implementation.

BIM Level 2 within SMEs in the UK.

SMEs play a significant role in the development of economies in countries across the world. Generally, the structure of the construction industry is made of many

organisations, where most of them are SMEs. These SMEs incorporate a workforce, materials, assets and information (Harty et al. 2016), and, according to Kotey et al. (2005), the management processes in SMEs are informal and, consequently, they encounter issues relating to health and safety and management (Eakin *et al*, 2000; Vassie *et al*, 2000). In addition, the workforce is small and less skilled than in larger companies, thus, they face problems of re-training when adopting new technology or methods of working.

Generally, when adopting new technologies, such as BIM, to encourage the construction sector to suggest appropriate policies, it is vital to consider the growth of BIM adoption by SMEs (Boktor *et al.,* 2013). Although large companies are willing to embrace BIM, smaller companies, especially SMEs, seem to be lagging behind. (SmartMarket Report, 2012). According to the SmartMarket Report (2012), the number of large companies adopting BIM is three times more than smaller companies. . In another version of SmartMarket Report published in 2014, it has been reported that there was a notable gap with regards to BIM adoption in organisations showing that 89% of large companies were ready for BIM adoption, while 54% of small companies were not (SmartMarket Report 2014) and Mellon and Kouider (2016), indicated that the gap between large companies and SMEs has widened since then.

According to Jamieson e*t al.* (2012), the policies and strategies in the UK to improve and innovate the sector, by adopting and implementing BIM level 2, seem to ignore the needs of SMEs. Consequently, they are not able to see how BIM will help them to improve the construction process, and especially to see the advantages and disadvantages of adopting the technology. Also, because the focus of BIM level 2 was on complex major projects in the public sector which necessitated collaborative procurement, many SMEs felt that BIM was not suitable for them (Jamieson et al., 2012). In addition, the cost of implementing even the first level of BIM, was one of the main barriers faced by SMEs, particularly when a large sum of money was needed to be spent over a short period of time. Therefore, SMEs in the UK are dropping behind in BIM level 2 implementation, and they are missing out on both publicly funded and private projects (Federation of Master Building 2013).

Obviously, there is a need for BIM Level 2 to be adapted for organisations of different sizes if it is to be used to deliver construction projects. Although, as shown above, SMEs, have received little consideration in strategies from government or the construction sector, or work by researchers. According to Dainty et al., (2017), the existing policies

were framed to serve companies which already have the power and resources for implementation, while other companies are left unnoticed. Proirer at al. (2015) suggested that in order to benefit, SMEs need a clear strategy to guide the adoption of BIM. However, Dainty et al. (2017) claimed that in reality only a few SMEs have the ability to develop an approach for BIM adoption and implementation. Also, due to the limited research on adoption by SMEs, they appear to have shown little interest in BIM (NBS 2014).

According to Blackwell (2012), SMEs could lose national and international projects if continue to lag behind with BIM adoption. Harris (2013) stated that this will result in an undesirable impact on them, and could make them less ambitious and competitive. This tendency will continue if SMEs do not start integrating this new technology into their organisations to meet the demands of government and industry. Also, the UK government have mandated the use of BIM Level 2 in all public projects by 2016 (British Standard Institute, 2013, which signifies that SMEs or any organisation which are not using BIM will be unable to bid for government projects (HM Government 2015). This will cause SMEs to bid only for private projects where BIM Level 2 is not a requirement. In recent studies, NBS (2017) reported that 52% of small firms have not used BIM Level 2 at all, and only 5% of small companies have made the effort to adopt and implement Level 3 (Hosseine et al. 2016).

CSFs Influencing BIM Level 2 Adoption and Implementation in SMEs.

Different studies have been carried out in order to understand the process of adopting BIM (NBS 2016; NBS 2017), and the factors which influence its adoption (Gu and London 2010; Linderoth 2010; Sawhney et al.2014; Xu et al. 2014). However, this will be the first paper reporting on the factors influencing the adoption and implementation of BIM Level 2 for SMEs.

In order to identify these factors, the researchers selected the articles which discussed the different methodologies for adopting BIM excluding any that did not address the aims of the research. Once all the relevant articles had been extracted, they were critically analysed in order to synthesise the data. Fifteen articles were selected for this study, which helped to classifying the factors into four main categories, based on the work of Enegbuna *et al.* (2015) and Ahn et al. (2016), which were: human factors, organisational factors, process factors and external factors. The factors selected were chosen based on their

frequency in the literature and their importance to BIM Level 2 implementation in SMEs as shown in Table 1 below.

Research Method

The objectives of this study were to investigate the CSFs for BIM Level 2 implementation in SMEs, and then according to their degree of influence on the process determine their importance. To achieve these objectives, 25 professionals from small and medium sized companies who were experienced in using BIM Level 2 were interviewed. The interviews were designed specifically for this study and allowed the participants to express their opinions freely. The questions were designed based on themes from previous literature which included: BIM level 2, implementation, human factors, organisational factors, process factors and external factors.

Data Collection and Case Studies

The case studies chosen for this research were selected from the bre.co.uk website and included all the businesses which were using BIM Level 2. On the website, 38 companies across the UK were selected differing in size, from large to small companies. Companies were then classified as SMEs based on the number of employees and their annual turnover. Based on this definition, 9 of those previously selected companies were considered as SMEs.

Initially, the researcher sent official emails to all nine companies to obtain their agreement to participate in the study and only 3 companies replied, and due to time constraints only these companies were considered for the research. Margarete (1995) stated that establishing the suitable sample size depended on the type of study, and in some studies, it was sufficient to have three to five case studies, and other studies needed more than five. Research by Yin (2010) found that qualitative research relied more on logical generalisation than statistical generalisation.

The researcher collected data from the three SMEs selected (CS1, CS2 and CS3) using semi-structured interviews. The type of the study required that the participants needed at least xxx years-experience of a BIM level 2 implementation. The participants were selected from both the management and technical levels of each company. Table 2 below shows for each company, the code assigned for each participant and their position in the company.

Data Analysis

The answers each participant interviewed were assigned a code and then categorised into themes for the analysis. According to Gray (2009), analysing qualitative data means explaining the data according to the theory, not just describing it. In this study, Nvivo software was used as a content-analysis technique, for the data obtained from the interviews. Content analysis is an effective way to analyse data in qualitative research. Though, according to Gray (2005) this method does not show the relationship between the variables in the research. Content analysis was used by the researcher to review and discuss the case study based on the responses from the interviews.

Findings

The findings emerged from this study were the critical success factors which influence the implementation of BIM level 2. The factors were classified in four main categories based on how they influence the implementation of BIM Level 2 in SMEs. Twelve critical factors were identified previously from reviewing the literature, in addition to three new factors recognized from the data collection process since they were crucial for the implementation of BIM Level 2 in the selected case studies.

1. Revised Factors Influencing BIM Level 2

The participants from the three case studies were asked to examine the factors identified from the literature, to identify those that they considered were important to the implementation, and to add any other factors they also thought were important.

Twelve CSFs were confirmed as important following the analysis of the data collected from the three case studies. These factors were classified in four main categories as following:

- Human factors (people and training of employees).
- Organisational factors (change management, top management support, available resources, software compatibility, BIM awareness and company vision/strategy).
- Process factors (BIM policy, communication and collaboration).
- External factors (government support and client demand).

Human Factors

The factors in this category were people and training of employees. The availability of people with the required experience and training is critical for the implementation of BIM (Khosrowshahi and Arayici 2012; Lee et al. 2015). According to the participants interviewed, to ensure a successful implementation. the implementation process for an information system such as BIM requires the employees to have particular skills and knowledge, As commented by ML2 in CS1:

"Skilled employees are essential for the implementation as well as them being open-minded to new ways of working".

Implementing BIM requires changing the way of working, thus training on the processes is critical in order to ensure that all employees have the required level of knowledge. It was found that in order to embrace the potential of BIM it is important that companies provide training on the process rather than just the use of software (Crowther and Ajayi 2019).

Organisation Factors

This category included factors from inside the organisation which influenced the implementation of BIM (Ahn et al. 2016) . Awareness at all levels in the organisation was critical as it could either facilitate or hinder the implementation (Turpin 2016). Ahankoob et al. (2019) highlighted the fact that previous awareness of BIM can minimise the impact of resistance to change on adoption. As commented by TL1 in CS2:

"When they heard about the plan to implement BIM was exposed, many participants said that they thought they had to learn how to use new software rather than new processes, therefore BIM awareness is crucial within the company at the early stages of implementation".

According to the literature, many scholars considered change management and top management support were very influential during the implementation. By providing the necessary training and financial support, barriers such as high costs and the problems of adapting to the new system can be overcome (Lee et al 2015; Enegbuma et al. 2015; Ahuja et al. 2018). As mentioned by ML2 in CS1:

"In order to implement BIM Level 2, the support and commitment of management is required to achieve better results and make decisions which can positively affect the progress and overall performance of the company".

Eastman et al. (2011) argued that good information exchange, the right software and hardware, and the availability of financial resources was vital to achieve a successful implementation of BIM. In addition, this was supported by Ganah and John (2013) who mentioned that an innovative process required a significant budget. Even if organisations are willing to adopt BIM, not having the available financial resources can impede the start of the process (Khosrowshahi and Arayici 2012). Also, it is critical to ensure the availability of compatible software, which will result in better communication between the parties and stakeholders involved in the process (Boktor et al. 2013). As commented by TL4:

"Purchasing compatible software was important to achieve the required level of information sharing within the organisation".

Process Factors

One of the most significant outcomes of BIM Level 2 is better communication and collaboration (Havenvid et al. 2016). However, Ganah and John (2013) argued that managing the whole process could be challenging and difficult and could result in conflicts and misunderstandings. However, proper communication and collaboration will help to avoid these issues. As mentioned by TL3 in CS3:

"Communication and collaboration were key to spreading BIM knowledge faster within the company".

On the other hand, Bradinath *et al. (*2016) commented that the available guidance for BIM, especially for integrating BIM with present practices in the construction sector, was limited. Consequently, most of the methods used by construction practitioners for implementing BIM without the appropriate guidance were ineffective and resulted in poor project management. Thus, Azhar (2011) argued that it was critical to standardise the processes and provide appropriate guidelines for the adoption of BIM, particularly when only a few SMEs had the ability to develop a clear strategy.

External Factors

Understanding the client requirements is a very important factor. Satisfaction of the client is critical, since the client defines the responsibility of the contractor and sometimes specifies the BIM level which should be used, which will affect the implementation of BIM (Amponsah 2010). NBS (2016) states that the client requirements are more important when the company is implementing Level 2, because it includes costing and scheduling elements where the needs are very specific to the company.

According to Eadie et al. (2015), government pressure was a factor influencing BIM Level 2 adoption especially in the UK construction Industry. A study presented by Ahmed (2018) showed that this factor has become more important since 2016, because the UK government has made the use of BIM Level 2 mandatory in public projects. As mentioned by ML1 in CS3:

"The adoption of BIM in the construction industry has been influenced by high client demand and the support offered by the government".

2. New Critical Success Factors (CSFs) Influencing BIM Level 2

From the analysis of the data obtained from the semi-structured interviews, three new critical factors were identified, which were: hiring an external consultant, control over performance and knowledge transfer. These are discussed below.

- ***Hiring an external consultant:***

This CSF was identified by participants in both CS1 and CS2. It was categorised as an external factor because the consultant was hired from outside the company. In case study CS1, this factor was identified as extremely important because they had no previous knowledge or experience of BIM technology. Consequently, the company had to hire an external BIM consultant to ensure that the implementation process would be successful. This factor was important for CS1, since the main duties of the consultant were: designing the implementation plan; controlling and supervising the implementation phase; training the employees and evaluating the final results of the implementation. As commented by TL1 in CS1:

"I was hired by the company to help in BIM level 2 implementation, my main responsibilities were designing the implementation plan, training the staff and controlling the performance".

The need to hire an external consultant was identified by participants in CS2. The participants commented that the help of a consultant was critical for the design of the implementation plan, training the employees on the new software and changing their mind-set to accept the new technology. As commented by ML1 in CS2:

"After the decision of adopting BIM was taken, we hired a consultant to help us design a plan which ensured the implementation of BIM Level 2".

In the case of CS3, participants said that there was no need for a consultant because they already had some experience and knowledge of BIM from working on projects where BIM was used. Consequently, they implemented BIM based on their own experience and understanding.

- ***Control of performance:***

This factor identified by participants in both CS1 and CS2. It was categorised as a process factor, due to its influence on the overall performance of the process. Participants commented that, management, with the help of the consultant, were responsible for controlling the performance of employees during the implementation stage to ensure that every task was delivered as planned. As per the words of TL1 in CS2:

"Controlling the performance and allocating evaluation measurements was very important to make sure the performance was stable through the entire life-cycle of the implementation".

The participants also commented that the performance was evaluated based on measurements set by management and the consultant. The evaluation criteria were the time and cost needed to deliver the project and the level of client satisfaction for the final product.

- ***Knowledge transfer:***

This factor was identified from the analysis of the interview results from CS3 and was categorised as an external factor. According to the participants, the knowledge and experience gained by working on overseas projects in Qatar and Dubai, and collaborating with international companies which used BIM, was invaluable for the transfer of this technology to their own company. As commented by ML1 in CS3:

"There are limited policies and guidelines which show the right way to implement BIM. However, in our case, the knowledge acquired from working with other international companies helped us to set the foundation for BIM".

The participants in CS1 and Cs2 did not see knowledge transfer as such as important factor as those in CS3 because none of them had previously worked for a company that used BIM. This could have been one of the reasons which led them to hire a consultant to assist in the implementation.

Figure 1 illustrates the factors influencing BIM Level 2 implementation in SMEs and places the factors into their respective categories.

3. Importance of Critical Success Factors (CSFs) Influencing BIM Level 2 Implementation

The aim of this research was to identify the CSFs influencing BIM Level 2 implementation, as well as identify the level of importance for each of the factors. The level of importance was determined by the 23 participants who were interviewed. It should be noted that participants in all three case studies gave the same level of importance to some of the factors. Although, some of the factors were given different levels of importance in the other case studies.

Table 3 below shows the level of importance given to each factor based on the combined responses from the participants in all three case studies. For instance, if a factor was stated as *medium* importance by most of the 25 participants, then the overall ranking was taken as **medium.** If a factor was not mentioned in one of the case studies, the symbol (-) was used to denote this. The judgment of the researcher also helped to identify the average importance for each factor. This interpretation by the researcher was derived from the

evidence in the literature and the responses provided by the participants during the interviews.

It can be seen from the table that BIM awareness and training have been ranked as *highly* important, as those factors influenced the capability, skills and mind-set of employees who used the new technology. It was found that it was easier to implement BIM if the companies had a previous knowledge of BIM and some experience in using this technology. For instance, in this study, the company in CS3 did not need to hire an external consultant since the implementation was based on their own knowledge. However, in case study 1 and 2, employees lacked the necessary knowledge and experience, therefore hiring an external consultant was necessary in order to achieve a successful implementation. The available BIM policies, continuous control of performance, client demand to use BIM Level 2 and government support were all identified as *medium* importance.

The compatibility of software and the availability of resources were ranked as *low* importance by the participants. It is important to note that although this was a low ranking in relation to the other factors, these factors are still critical for the implementation of BIM Level 2.

Conclusion

This study has found that the true potential of BIM for SMEs in the UK construction sector has not yet been realised. The literature showed that the adoption rate of the technology in SMEs has been slower than in larger companies.. This low rate of adoption was due to limited resources, lack of expertise, high initial cost of implementation and limited research addressing the implementation of BIM in small and medium sized companies. In 2016, the UK government mandated the use of BIM Level 2 in all public projects, which meant that SMEs stopped bidding for them and bid instead for private projects where BIM was not required. Therefore, this study addressed this issue by identifying 15 critical success factors which influenced the implementation of BIM Level 2 within SMEs. These factors were identified by interviewing 25 BIM professionals working in three different companies in the UK. The findings confirmed the 12 CSFs identified previously in the literature as shown in Table 1 below. Additionally, three new CSFs were identified from the interviews, which were: support from an external consultant, control of performance and knowledge transfer. These new factors were

classified under: external factors (external consultant and knowledge transfer) and process factors (control of performance). Then, based on the responses provided by the participants, the importance of these factors throughout the implementation process was determined. This importance was based on a scale of high, medium and low (see table 3 below).

This study contributes to theory by identifying 15 CSFs influencing the implementation of BIM Level 2 in SMEs. This will enrich the body of knowledge of BIM due to the limited research on this topic, and the identification of three new CSFs can be considered to be a significant contribution.

Limitations of the study are firstly that only three case studies were taken into consideration, which will make the generalisation of the results difficult, and secondly that well as only a qualitative method was used in this study. Future studies can investigate BIM Level 2 using a mixed-method approach in order to develop a more detailed implementation strategy for SMEs.

Acknowledgements

We would like to thank the participants who provided the data for this study.

Disclosure statement

No potential conflict of interest was reported by the authors.

References

Ahankoob, A., Manley, K. and Abbasnejad, B. (2019) "The Role Of Contractors' Building Information Modelling (BIM) Experience In Realising The Potential Values Of BIM". *International Journal Of Construction Management* 1-12

Ahmed, S. (2018). Barriers to Implementation of Building Information Modeling (BIM) to the Construction Industry: A Review. *Journal of Civil Engineering and Construction*, 7(2), p.107.

Ahn Y, H., Kwak Y, H. and Suk S, J., (2016) Contractors' Transformation strategies for Adopting Building Information Modeling *J. of Management in Engineering* **32**(1) 1

Ahuja, R., Sawhney, A., Jain, M., Arif, M. and Rakshit, S. (2018) "Factors Influencing BIM Adoption In Emerging Markets – The Case Of India". *International Journal Of Construction Management* 1-12

Amponsah, C. T. (2010). "Public-private partnerships: Critical success factors for procurements of capital projects." Ph.D. thesis, Capella Univ., Minneapolis.

Arayici , Y., et al. (2009), Towards implementation of Building Information Modelling in the construction industry, in Fifth International Conference on Construction in the

21st Century (CITC-V). Collaboration and Integration in Engineering, Management and Technology, May 20-22, 2009, Istanbul, Turkey.

Arayici, Y., Coates, P., Koskela, L., Kagioglou, M., Usher, C. & O'Reilly, K. (2011) Technology adoption in the BIM implementation for lean architectural practice. Automation in Construction, 20(2), pp.189-195

Azhar, S. (2011). Building information modeling (BIM): Trends, benefits, risks, and challenges for the AEC industry. Leadership and Management in Engineering, 11(3), 241–252. DOI:10.1061/(ASCE)LM.1943-5630.0000127

Badrinath, A. C., Chang, Y. T., Hsieh, S. H. (2016) An Overview of Global Research Trends in BIM from Analysis of BIM Publications. 16th international conference on computing in civil and building engineering, ICCCBE 2016 - July 6th-8th, At Osaka, Japan.

Becerik-Gerber B, Jazizadeh F, Li N, Calis G. (2012). Application areas and data requirements for BIM-Enabled facilities management. J Constr Eng Manag. 138:431–442.

Bernstein, P.G. and Pittman, J.H. (2004), Barriers to the adoption of building information modelling in the building industry, White paper, Autodesk Building Solutions.

Bew, M. and Richards, M. (2008), Bew-Richards BIM maturity model, BuildingSMART,Construct IT Autumn Members Meeting, Brighton.

British Standard Institute. (2013). Industrial strategy: Government and industry in partnership: Construction 2025. London: Department for Business, Innovation & Skills

Blackwell, B. (2012) Industrial strategy: Government and industry in partnership – Building Information Modelling. HM Government.

Boktor, J., Hanna, A., Menassa, C.C. (2013) The state of practice of building information modeling (BIM) in the mechanical construction industry. Journal of Management in Engineering, 30(1), pp. 78-85.

Boutle, A. (2017). UK BIM adoption: reality is difficult to fathom. Retrieved on 05 April 2018, from: http://www.bimplus.co.uk/people/uk-bim-adopt7ion-rea6lity-diffic8ult-fathom/.

Bryde, D., Broquetas, M., & Volm, J. M. (2013). The project benefits of building information modelling (BIM). *International Journal of Project Management, 31* (7), pp. 971-980.

Cabinet Office (2012). Government Construction Strategy, Available from: https://www.gov.uk/government/uploads/system/uploads/attachment data/file/61152/Government-Construction-Strategy_0.pdf, [Accessed: 12th May 2019]

Corporate-body.GROW:Directorate-General for Internal Market, E. (2019) *User Guide To The SME Definition.* [online] available from

<https://publications.europa.eu/en/publication-detail/-/publication/79c0ce87-f4dc-11e6-8a35-01aa75ed71a1> [9 September 2019]

Crowther J, Arayici, Y. (2019). Impacts of 4D BIM on construction project performance. Int J Constr Manage. 1–14. doi: 10.1080/15623599.2019.1580832

Dainty, A., Leiringer, R., Fernie, S. and Harty, C. (2017) "BIM And The Small Construction Firm: A Critical Perspective". Building Research & Information 45 (6), 696-709

Department for Business Innovation & Skills (2014). UK Construction: An economic analysis of the sector. July 2014

Doolin B, Al Haj Ali E. (2008). Adoption of mobile technology in the supply chain. Int J E-bus Res. 4:1–15.

Dunton, J. (2016). Survey shows profession uncertain over new BIM rules. Retrieved on 26 April 2017, from: https://www.architectsjournal.co.uk/news/survey-shows-profession-uncertain-over-new-bim-rules/10004804.article.

Eadie, R., Browne, M., Odeyinka, H., McKeown, C., & McNiff, S. (2015). A survey of current status of and perceived changes required for BIM adoption in the UK. Built Environment Project and Asset Management, 5(1), 4–21. doi:10.1108/BEPAM-07-2013-0023

Eakin, J., Lamm, F., Limborg, H (2000) International perspective on the promotion of healthand safety in small workplaces. Cited in Systematic OHS Management: Perspectives on an International Development. Netherland: Elsevier.

Eastman, C., Teicholz, P., Sack, R., Liston, K. (2011) BIM Handbook: A guide to Building Information Modeling for Owners, Managers, Designers, Engineers, and Contractors. 2nded. The United States of America: John Wiley & Son, Inc.

Enegbuma, WI., Aliagha, GU and Ali, KN. (2015). Effects of perceptions on BIM adoption in Malaysian construction industry. Journal of Technology. 77 (15), 69-75.

Federation of Master Builders (2013). Improving public procurement for construction SMEs. UK: Federation of Master Builders.

Ganah, A., and John, G. (2013). "Suitability of BIM for enhancing value on PPP projects for the benefit of the public sector." Public Private Partnership Int. Conf. 2013 Body of Knowledge, Univ. of Central Lancashire, Preston, U.K., 347–356.

Ghaffarianhoseini, A., Tookey, J., Naismith, A., Azhar, S., Efimova, O. and Raahemifar, K. (2017) "Building Information Modelling: Clear Benefits, Understanding its Implementation, Risk and Challenges". Renewable and Sustainable Energy Reviews75, 1046-1053

Gray, D. E. (2009) *Doing Research in the Real World,* California: SAGE Publications/Thousand Oaks

Gray, D .F. (2005). *The observation and analysis of stellar photospheres*. Cambridge University Press

Gu, N. and London, K. (2010) Understanding and facilitating BIM adoption in the AEC industry. *Automation in Construction*, 19(8):988-999.

Hanna, A., Boodai, F. and El Asmar, M. (2013) "State of Practice of Building Information Modeling In Mechanical and Electrical Construction Industries". *Journal of Construction Engineering and Management* 139 (10), 04013009

Harris, R., McAdam, R., McCausland, I. and Reid, R. (2013) "Levels Of Innovation Within Smes In Peripheral Regions: The Role Of Business Improvement Initiatives". *Journal Of Small Business And Enterprise Development* 20 (1), 102-124

Harty, J., Kouider, T., Paterson, G (2016) Getting to Grips with BIM. London and New York: Routledge Taylor & Francis Group

Havenvid, M., Hulthén, K., Linné, Å. and Sundquist, V. (2016) "Renewal In Construction Projects: Tracing Effects Of Client Requirements". *Construction Management And Economics* 34 (11), 790-807

HM Government. (2015). Digital build Britain: Level 3 building information modelling – strategic plan. London: HM Government

HM Government (2012), Industrial strategy: government and industry in partnership: Building Information Modelling, Crown, Blackwell,Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/34710/12-1327-building-informationmodelling.pdf

Hosseini, M. R., Banihashemi, S., Chileshe, N., Namzadi, M. O., Udaeja, C., Rameezdeen, R., & McCuen, T. (2016). BIM adoption within Australian small and medium-sized enterprises (SMEs): An innovation diffusion model. Construction Economics and Building, 16(3), 71–86. doi:10.5130/AJCEB.v16i3.5159

Hunt, S. (2015). Steven Hunt: No-one is ready" for 2016 BIM Level 2 mandate.(online) available from: http://bimcrunch.com/2015/08/steven-hunt-no-one-is-ready-for-2016-bim-level-2-mandate/. [Accessed 20/09/2018]

Jamieson, D., Fettiplace, S., York, C., Lambourne, E., Braidford, P., Stone, I. (2012). Large Businesses and SMEs: Exploring how SMEs interact with large businesses. ORC International, July 8.

Joo, M., Jung, Y. (2011) Building Information Modelling (BIM) a Framework for practical implementation. Automation Construction. 20, pp.126-133.

Khosrowshahi, F. and Y. Arayici, (2012) Roadmap for implementation of BIM in the UK construction industry. Engineering, Construction and Architectural Management, 19(6):610-635.

Kotey, B., Slade, P (2005) Formal human resource management in small growing firms.Journal of small business management, 43(1), pp.25-41.

KPMG (2016). KPMG annual report: a clear insight. (online) Available from: https://assets.kpmg/content/dam/kpmg/uk/pdf/2016/12/annual-report-2016.pdf [accessed on 14/08/2019].

Lee, S., Yu, J. and Jeong, D. (2015) "BIM Acceptance Model in Construction Organizations". Journal of Management in Engineering 31 (3), 04014048

Linderoth, H. C. (2010). Understanding adoption and use of BIM as the creation of actor networks. Automation in Construction, 19(1), 66–72. doi:10.1016/j.autcon.2009.09.003

Margarete S., (1995). ”Focus on Qualitative Methods Sample Size in Qualitative Research “, Research in Nursing & Health, Vol. 18, pp. 179-183.

McGraw-Hill Construction. (2014). The business value of BIM for construction in major global markets. New York: McGraw-Hill Construction.

Mellon, S., & Kouider, T. (2016). SMEs and Level 2 BIM, The way forward. In A. G. Garrigós, & T. Kouider (Eds.), Healthy buildings: Innovation, design & technology, ICAT 2016: Conference proceedings of the 6th international 708 A. DAINTY ET AL. congress of architectural technology, University of Alicante 12–14 May 2016 (pp. 121–135). San Vicente del Raspeig: Universidad de Alicante.

Miettinen R. and Paavola S., (2014) Beyond the BIM utopia: Approaches to the development and implementation of building information modeling. Automation in Construction, 43: 84-91.
Morlhon R., Pellerin R., and Bourgault M. (2014) Building Information Modeling Implementation through Maturity Evaluation and Critical Success Factors Management. *Procedia Technology*, 16: 1126-1134.

Myers, D. (2013). Construction economics: A new approach. London & New York: Routledge.

NBS (2014) BIM levels explained. 01 November 2014 [online]. Available at https://www.thenbs.com/knowledge/bim-levels-explained. [Accessed 30/7/2019].

NBS (2016). NBS national BIM report 2012. Newcastle: National Building Specification.

NBS (2017). NBS national BIM report 2012. Newcastle: National Building Specification.

NIBS (2007) National Building Information Modeling Standard (NBIMS), Washington DC.

Peansupap, V, Walker, D. H. (2005) Factors enabling information and communication technology diffusion and actual implementation in construction organisations. Journal of Information Technology in Construction (ITcon), 10(14), pp.193-218.

Poirier, E, Staub-French, S, & Forgues, D. (2015). Embedded contexts of innovation: BIM adoption and implementation for a specialty contracting SME. Construction Innovation, 15 (1), 42–65. doi:10.1108/CI-01-2014-0013

Robson, A, Boyd, D. & Thurairajah, N. (2014). UK Construction Supply Chain Attitudes to BIM. In 50th ASC Annual International Conference Proceeding. March, Birmingham, UK.

Sawhney A, Agnihotri R, Kumar Paul V. (2014). Grand challenges for the Indian construction industry. Built Environ Proj Asset Manag. 4:317–334.

SmartMarket Report. (2012) The Business Value of BIM in North America: Multi-Year Trend Analysis and User Ratings (2007–2012). Bedford: McGraw- Hill Construction.

SmartMarket Report. (2014) The Business Value of BIM for Construction in Major Global Markets: How Contractors Around the World Are Driving Innovation with Building Information Modelling. Bedford: McGraw- Hill Construction.

Stewart, R. A., Mohamed, S., Marosszeky, M. (2004). An empirical investigation into the link between information technology implementation barriers and coping strategies in the Australian construction industry. Construction Innovation, 4(3), pp.155-171.

Succar, B. (2009). Building information modelling framework: A research and delivery foundation for industry stakeholders. Automation in Construction, 18(3), 357–375. doi:10.1016/j.autcon.2008.10.003

Turpin, M. (2016). It's time to forget BIM Level 2, [online], available from: http://www.bimplus.co.uk/people/its-ti8me-for5get-bi4m-level-2/ [accessed 15/04/2019]

Vassie, L., Tomas, J, m, Oliver, A. (2000). Health and safety management in UK and Spanish SMEs: a comparative study. *Journal of Safety Research.* 31(1), pp.35-43.

Wong, A. K., Wong, F. K., & Nadeem, A. (2010). Attributes of building information modelling implementations in various countries. Architectural Engineering and Design Management, 6(4), 288–302. doi:10.3763/aedm.2010.IDDS6

Wu C., Xu B., Mao C., Li X., (2017) Overview of BIM maturity measurement tools, ITcon Vol. 22, pg. 34-62, , [online], available: http://www.itcon.org/2017/3 [Accessed 17 May 2017]

Xu H, Feng J, Li S. (2014). Users-orientated evaluation of building information model in the Chinese construction industry. Autom Constr. 39:32–46; available from: http://www.sciencedirect.com/science/article/pii/ S092658051300216 [accessed 2019 August 10].

Zakaria Z, Mohamed Ali N, Haron A. T., Ponting A. M, and Abd Hamid Z (2013) Exploring the adoption of Building Information Modelling (BIM) in the Malaysian construction industry: A qualitative approach. *IJERT: Int. J. of Research in Eng. and Tech.* **2**(8) 384

Zuppa, D., Raja R., Issa A., Suermann P, C. (2009) BIM's impact on the success measures of construction projects, *Computing in Civil Engineering,* pp.503–512.

Table 1. CSFs influencing BIM Level 2 implementation in SMEs.

Category	Critical Success Factors	Definition	Cited by
Human Factors	People	Availability of qualified people within the company	NIBS (2007), HM Government (2012), Wong et al. (2010), Succar (2009), Khosrowshahi and Arayici (2012) and Lee et al. (2015)
	Training	Equipping the personnel with necessary knowledge and skills through training programs, seminars	Zuppa et al. (2009), Joo and Jung (2011), Arayici et al. (2011), Khosrowshahi and Arayici (2012), Succar (2009) McGrawHill Construction (2014) and Crowther and Arayici (2019)
Organisation Factors	BIM Awareness	Existence of awareness and knowledge of BIM Level 2 within the company	Succar (2009), Arayici et al. (2011), Khosrowshahi and Arayici (2012), Turpin (2016); NBS (2014), Ahankoob (2019)
	Change Management	Manage and change people in the company to achieve the required business outcomes.	Gu and London (2010), Joo and Jung (2011), Enegbuma et al (2015), Morlhon et al (2014)
	Top Management Support	Facilitate BIM implementation from top management by enabling resources, funds and assistance	HM Government (2012), Enegbuma (2015), Succar (2009), Arayici et al. (2011) Lee et al. (2015) and Ahuja et al. (2018)
	Company Vision and Strategy	Aligning the benefits offered by BIM with the vision and strategy of the company	Becerik-Gerber and Rice (2010), Azhar (2011), Hanna et al. (2013), Turpin (2016)
	Compatibility	A characteristic which allows software to operate together	Bernstein and Pittman (2004), Becerik-Gerber et al (2012), Azhar (2011), Hanna et al. (2013), HM Government (2012), Arayici and Coates (2012), Khosrowshahi and Arayici (2012), and Boktor et al. (2013)
	Resources	Availability of resources as: software, hardware and budget	Miettinen and Paavola (2014), Ganah and John (2013), Bryde et al. (2013), Linderoth (2010), Succar et al. (2009),

			Wong et al. (2010), and McGraw Hill Construction (2014)
Process Factors	Communication and Collaboration	Effective communication and collaboration during the process of implementation	Succar (2009), Eastman (2011), McGraw Hill Construction (2014), Ganah and John (2013), Peansupap (2005) and (Havenvid et al. 2016).
	BIM Policies	Existence and efficiency of a plan to implement BIM	Khosrowshahi and Arayici (2012), Becerik-Gerber et al. (2012), and Joo and Jung (2011), Bradinath *et al.* (2016)
External factors	Government Support	Pressure from the government to mandate a mandatory use of BIM Level 2 to deliver projects	Arayici et al. (2009), Succar (2009), Azhar (2011), NBS (2017), Eadie et al (2015) Wong et al (2010) Ahmed (2018), Zakaria et al (2013)
	Client Demand	Existence of pressure exerted by the client	NBS (2016), NBS (2017), Ahmed (2018), Turpin (2016) Ghaffarianhosein et al (2017), Ganah and John (2013), Doolin and Al Haj Ali (2008)

Table 2. Classification code of participants

Classification Code	Role in the company	CS1	CS2	CS3
ML1	**Director**	-	1	2
ML2	**Project Manager**	1	1	2
TL1	**BIM Manager**	1	2	1
TL2	**Design Manager**	-	1	1
TL3	**Architecture**	2	3	3
TL4	**IT Engineer**	-	-	1
TL5	**Revit Specialist**	2	-	-
TL6	**Mechanical Engineer**	1	-	-
Total		7	8	10

Table 3. Importance of the factors influencing BIM Level 2 implementation from the three case studies.

Factor Categories	*Factors Influencing BIM Level 2*	*CS1=7 Participants*			*CS2= 8 Participants*			*CS3= 10 Participants*			*Overall/ 25 Participants*			*Average of Importance*
		H	**M**	**L**	**H**	**M**	**L**	**H**	**M**	**L**	**H**	**M**	**L**	
Human Factors	People	2	1	4	3	5	0	1	6	3	6	12	7	**M**
	Training of employees	6	1	0	6	2	0	9	1	0	21	4	0	**H**
Organisation Factors	Change management	2	4	1	3	5	0	3	7	0	8	16	1	**M**
	Top management Support	6	1	0	6	2	0	7	3	0	19	6	0	**H**
	BIM awareness	6	1	0	8	0	0	7	3	0	21	4	0	**H**
	Available resources	2	2	3	1	2	5	1	2	7	4	6	15	**L**
	Software/Hardware compatibility	2	2	3	0	2	6	1	3	6	3	7	15	**L**
	Company vision and strategy	2	4	1	1	4	3	2	6	2	5	14	6	**M**
Process Factors	Communication and Collaboration	5	2	0	6	2	0	8	2	0	19	6	0	**H**
	BIM policy	2	4	1	1	5	2	0	7	3	3	16	6	**M**
	Control of performance	2	1	4	5	3	0	2	8	0	9	12	4	**M**
External Factors	Governmental support	2	4	1	1	4	3	1	8	1	4	16	5	**M**
	Client demand	2	3	2	2	4	2	2	6	2	6	13	6	**M**
	Support from an External consultant	6	1	0	3	5	0	-	-	-	9	6	0	**H**
	Knowledge Transfer	-	-	-	-	-	-	7	3	0	7	3	0	**H**

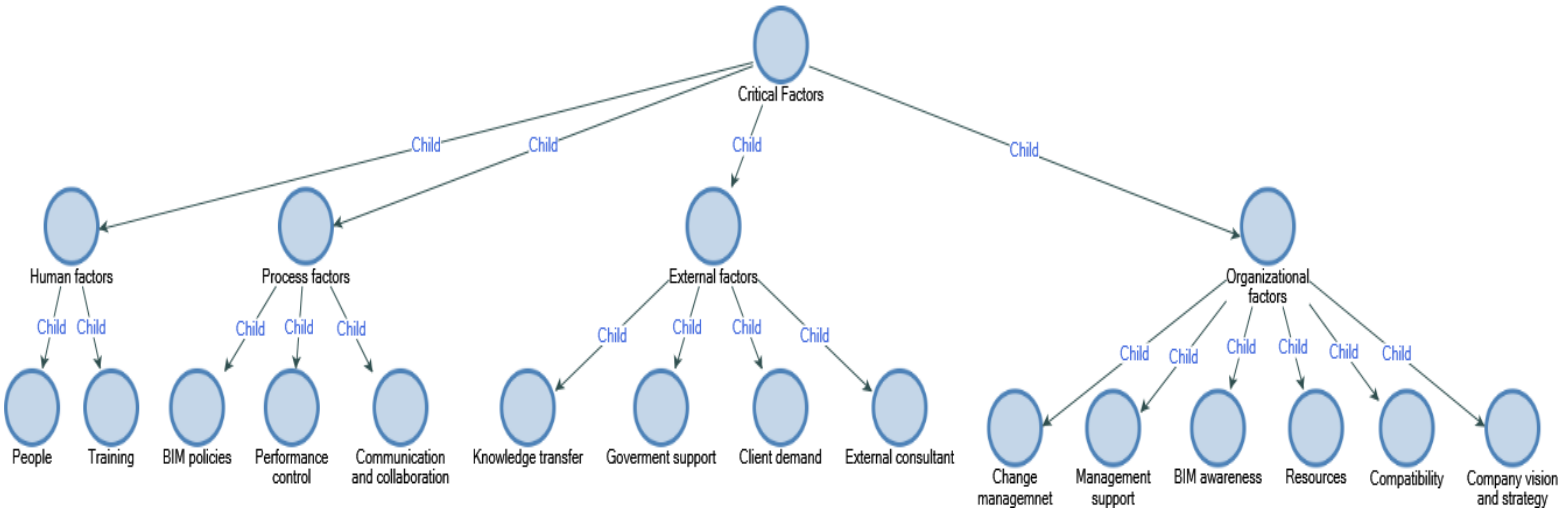

Figure 1. Revised Factors for BIM Level 2 Implementation in SMEs.